CHAPTER 5

Choosing between Centers of Action

Instrument Buoys, El Niño, and Scientific Internationalism in the Pacific, 1957–1982

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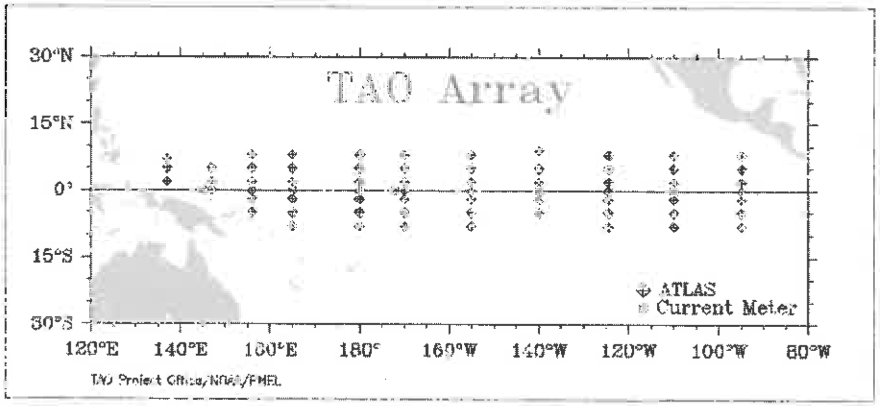
In 1997, Pacific Ocean scientists finally had the instrument of their dreams to observe the onset of a major El Niño-Southern Oscillation (ENSO) event: a network of moored buoys that produced surface and subsurface observations of an 8,000-mile swath of the equatorial ocean and transmitted them rapidly via satellite to meteorologists and oceanographers around the globe (Figures 1 and 2). This vast instrument array allowed scientists to monitor, in real time and unprecedented detail, the development of the most powerful ENSO event of the twentieth century. Their forecasts provided governing officials around the world with enough lead time and accuracy to implement mitigation plans that probably saved hundreds of lives and prevented billions of dollars of damage.[1]

Contrast this to the situation in 1982, when the next-strongest ENSO event of the century materialized. Rather than a fixed buoy system, environmental scientists depended primarily on weather satellites to monitor sea-surface conditions in the tropical Pacific. Unfortunately, reflective aerosols injected into the upper atmosphere by the eruption of El Chichón in southern Mexico in April 1982 upset satellite calibration and blinded remote observers to the onset of this event. Of course, satellites could not peer under the waves to observe subsurface changes. Data from the handful of



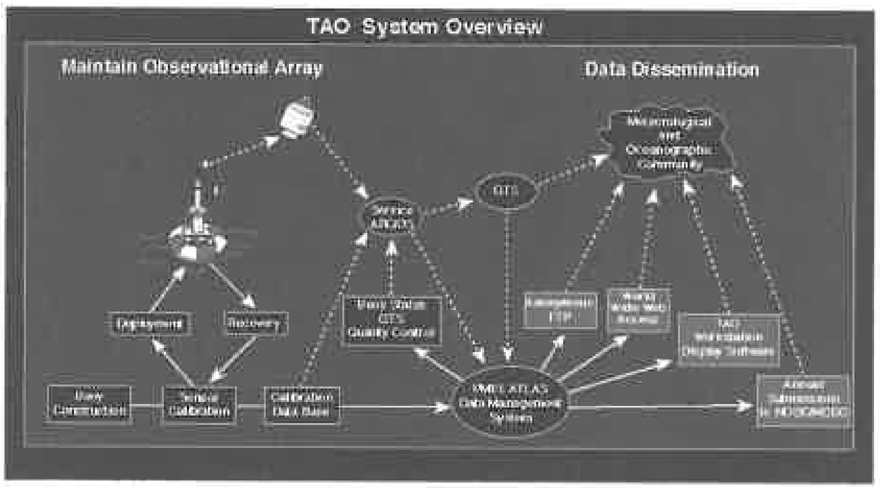


FIGURE 1. Tropical Ocean Global Atmosphere/Tropical Atmosphere Ocean (TOGA/TAO) instrument buoy array and observation system, circa 1997.

observatories that did exist in the equatorial Pacific (including a couple of experimental instrument buoys) was not readily available to meteorologists. It typically took weeks or months to obtain information from this region, by which time it was useless for making forecasts. Moreover, the handful of direct ocean measurements that did make it in a timely fashion into the hands of forecasters in 1982 were so anomalous that few trusted their accuracy. In retrospect, scientists realized a network of moored buoys in the region and

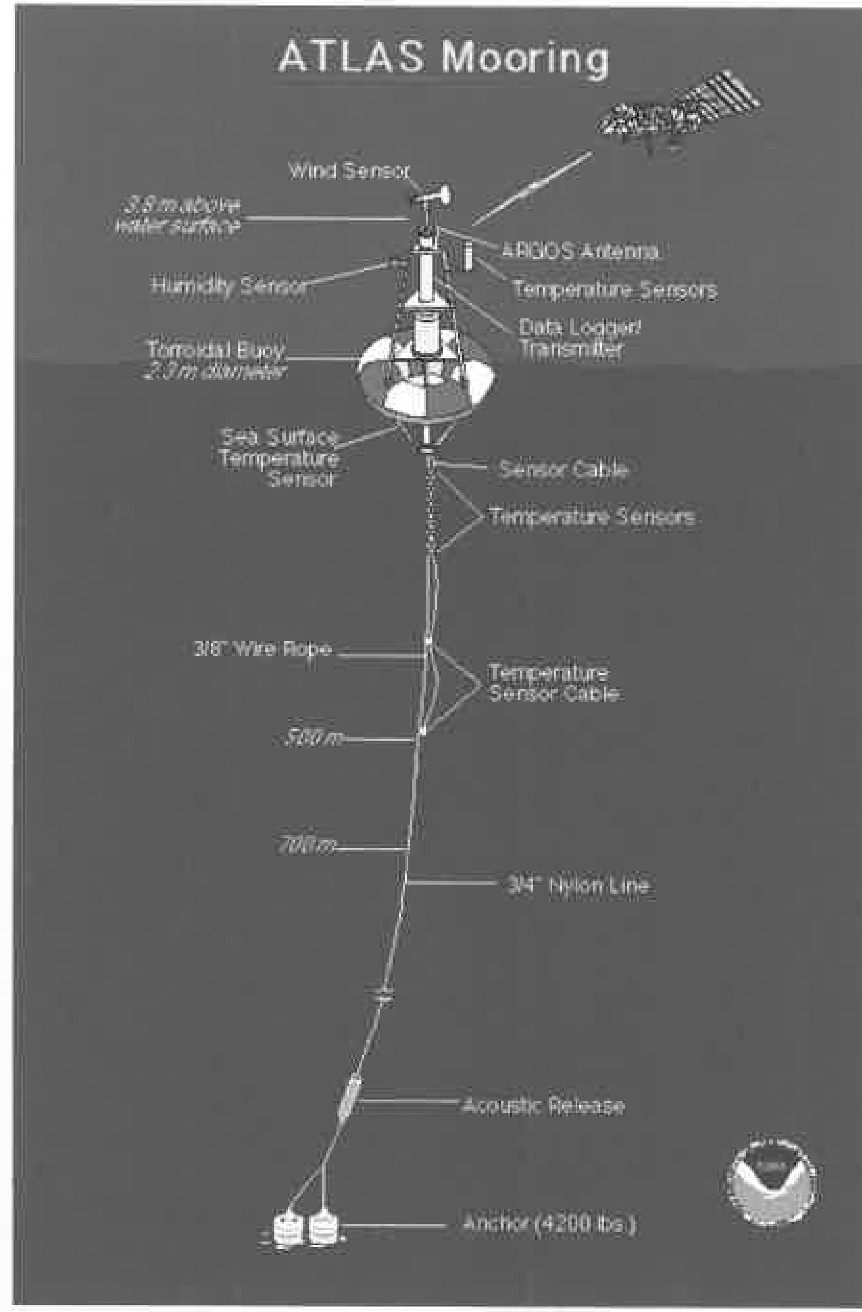


FIGURE 2. ATLAS moored instrument buoy used by TOGA/TAO.

better data sharing would have gone a long way toward resolving these problems. Beginning in 1984, a team based at the United States' National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory in Seattle planned and implemented the Tropical Ocean Global Atmosphere/Tropical Atmosphere Ocean (TOGA/TAO) project. By 1995, it had installed a network of 70 buoys in the equatorial Pacific costing US$50,000 each.[2]

Now that environmental scientists recognize ENSO as one of the most important mechanisms responsible for year-to-year variation in the earth's climate and look to the equatorial Pacific Ocean as the "center of action" for these changes, it is tempting to portray these events in teleological terms, as a heroic "quest to uncover the secrets" of "a mysterious phenomenon" using a promising new technology. That is exactly what the popular science television program NOVA set out to accomplish in its brief history of the TOGA/TAO array.[3] It is understandable that we want to celebrate these triumphs of human ingenuity. Why else do we spend such enormous sums to build scientific instruments on this vast geographic scale? By recruiting public support, such stories reinforce existing systems of patronage for Big Science. But they tell us little about how such projects become reality, much less commemorate the scientific problems, technologies, scientists—even entire regions of the world—that were neglected along the way to these triumphs.

This chapter will focus on an earlier phase of the drive by North American oceanographers and meteorologists to establish an improved observation network to monitor climate anomalies in the Pacific Basin. The Pacific Ocean's enormous extent and sparse settlement has always forced scientists to look for simplifying generalizations and observational short cuts in order to understand large-scale phenomena in the region.[4] Based on knowledge of the Atlantic, meteorologists have long suspected that certain "centers of action" in the Pacific are much more important to weather generation than others. From 1957 to 1982, scientific debate in the United States over how best to monitor the Pacific sought to decide which of these "centers of action" most deserved attention. A small vanguard of West Coast meteorologists and oceanographers consistently presented air-sea interactions in the equatorial Pacific and their "teleconnections" to weather over North America as vital to understanding the general circulation of the atmosphere and improving long-range weather prediction. This group vocally promoted the development of instrument buoys to improve monitoring of the equatorial Pacific. Nevertheless, their concerns were pushed to the sidelines in the course of planning the North Pacific Study, the first oceanographic project

to install an observational buoy array in the Pacific. Only dogged persistence made them a part of the North Pacific Experiment (NORPAX).

Four shifts in the political centers of action affecting marine science in the United States during this period influenced this choice between centers of action in the Pacific. First, meteorologists and oceanographers developed a new, shared research domain to investigate air-sea interactions. This trend had direct roots in an unfulfilled project of the "Bergen school," a classic research school that successfully transformed meteorology into a modern, geophysical science.[5] This study illustrates the political difficulties entailed by the creation of a new crossover discipline without a clearly defined patronage network.[6]

Second, this choice between centers of action involved the redefinition of what constituted the proper way to organize large-scale oceanographic projects. Increasing demands for accountability in Big Science in the mid-1960s, symbolized by the Defense Department's Project Hindsight and the failed Mohole Drilling Project, encouraged hierarchical and geographical centralization of authority and discouraged multi-institution, multi-national, catch-all projects in oceanography. Nevertheless, individual scientists still found ways to pursue their own interests under these pressures.[7]

Third, the extension of the U.S. fishing industry to the rich tropical waters of the eastern Pacific and the emergence of Peru as the world's largest fish-producing nation created a new vested interest for scientific research in this region.[8] This shift cemented Southern California's position as *the* center of action for Pacific oceanography, and established it as a major center for climate change research, as well, even as fishery science became peripheral to air-sea interaction studies.

Fourth, and most importantly, changes in Cold War geopolitics altered how marine scientists and their patrons perceived the tense relationship between "scientific internationalism" and "U.S. national interest" in Pacific science. Historians of Cold War science have convincingly demonstrated how national security concerns and weapons development influenced the patronage of science, the formation of new disciplines, and the basic nature of the scientific knowledge produced by the United States' "military-industrial-academic complex." For a variety of reasons, historians have focused on the hegemonic East-West dynamics of these security concerns during the period before 1960.[9] But North-South relations also powerfully influenced Cold War science, particularly the social sciences. This was especially true during the 1960s when "containment" and "modernization" were watchwords for U.S. foreign policy.[10] Such concerns helped make the Pacific coast of South

America a "hot spot" for marine science for over a decade. They demonstrably inspired U.S. planners to include Latin American scientists and institutions as part of the growing oceanographic observation network in the Pacific—in order to bring them in from the "periphery" of Third World science as allies of the First World.[11]

The equatorial Pacific continued to fall through the gaps of this network. Ultimately, the equator came close to being excluded as an oceanographic "center of action" from NORPAX, not because it lacked climatic importance, but because this region—and the scientists and institutions most closely associated with it—was too far removed from the interests of those nearest to the political "centers of action" of U.S. oceanography. This case ratifies the observation that technological systems embody the politics shaping their invention. In the process of planning this observation network, the web of social relationships that defines the authority of individual scientists became "hard-wired" to specific regions and institutions. These relationships, in turn, delimited what it was possible to know about the Pacific environment.[12]

1957–1958, "A YEAR OF CHANGE"

Strange climatic phenomena affected almost the entire Pacific Basin in 1957. Off the coast of California, sport fishermen caught more than 2,800 tropical dolphinfish versus the previous record of 15 in 1947. The average summer sea surface temperature at the Scripps Institution of Oceanography (SIO) pier was the highest measured since 1931. In the middle of the North Pacific, an enormous water mass up to 3°C warmer than normal persisted for months, and the North Pacific low near the Aleutian Islands was much stronger and generated more cyclonic storms than usual. Further abroad, "Hawaii had its first recorded typhoon; the seabird-killing *El Niño* visited the Peruvian Coast; the ice went out of Point Barrow at the earliest time in history; and on the Pacific's Western rim, the tropical rainy season lingered six weeks beyond its appointed term." Canton Island, a dry coral ring in the central equatorial Pacific where the U.S. Air Force operated an isolated meteorological observatory on the Honolulu-Samoa air route, became "lush with the seedlings of countless tropical trees and vines" after "great rafts of sea-borne seeds and heavy rains . . . visited her barren shores." These anomalies continued into 1958.[13] California marine scientists followed these portents with great interest, hoping they foretold the recovery of the collapsed California sardine fishery.[14]

This event happened to correspond with the International Geophysical Year (IGY, July 1957–December 1958), a collaborative science project of unprecedented scope and scale that played a crucial role in the establishment of "earth science" as a truly global field of study.[15] Sixty-five independent states and dozens of colonial territories participated. As a continuation of the International Polar Years (1882–1883, 1932–1933), the IGY focused especially on the Antarctic and Arctic. It also made extensive use of new technologies to probe the upper atmosphere and ocean depths. Ever since, the IGY has been widely recognized as an exemplar of internationalism in science.[16] Nevertheless, the collaborative nature of the IGY did not preclude geopolitical competition: the "space race" between the U.S. and U.S.S.R. received a powerful impetus from the launching of Sputnik and other satellites as part of the IGY program.[17]

International collaboration had other limitations during the IGY. The tropics received relatively little attention, with one major exception. The Scripps Institution of Oceanography established 16 new observatories and organized three major cruises in the equatorial and southern Pacific. As part of a long-standing openness to development projects emanating from the North, several Latin American countries welcomed the opportunity to improve their marine science capabilities by working with the SIO in these endeavors. As a whole, the U.S.-IGY program established climate observatories and collaborative data-sharing agreements for over 40 locations in the tropical Americas and Pacific.[18] Such activities were hardly free of imperialist overtones. The fact that the U.S. served as the "World Data Center" and primary organizer for IGY activities in Latin America, the Caribbean, and much of the Pacific meant that U.S. interests tended to determine the sort of science done in these domains. In the case of tropical meteorology, improvements in local prediction received little consideration, even though this was a primary concern of regional officials.[19]

John Isaacs, the technology-minded director of the Marine Life Research Institute at SIO, thought it was a good idea under these circumstances to call an informal scientific meeting to discuss the "meteorological, oceanographic and biological" features of this "year of change." Thanks to a suggestion by his internationally minded friend Warren S. Wooster—who was working at the time as director of marine science investigations for the Peruvian government—Isaacs decided not to limit discussion to the North Pacific Ocean.

Instead, the conference would address "the general circulation of the Pacific as a whole." Isaacs brought Wooster all the way from Peru to report on "El Niño." To help the oceanographers and fishery scientists who made up the bulk of Isaac's invitees understand the atmospheric component of this circulation, he had the prescience to invite two prominent meteorologists from the East Coast: Jule Charney, a theoretician and leading force in numerical forecasting, and Jerome Namias, a long-range forecaster and regular visitor to Woods Hole Oceanographic Institute. This pair had the closest of ties to the old Bergen school: Charney had been trained initially by Jacob Bjerknes, Jörgen Holmboe, and Arnt Eliassen at UCLA, Namias by Carl-Gustaf Rossby at MIT. Both maintained close connections to Rossby's Institute of Meteorology at the University of Stockholm, and both had a deep-seated interest in an improved observation network in the Pacific Basin. Roger Revelle, the busy director of Scripps and long-time promoter of both naval patronage and internationalism in marine science, deemed Isaacs's symposium important enough to rush back from Washington where he was working on the IGY just so he could attend.[20]

Thanks to Wooster and Namias, attendees of the June 1958 symposium at the Rancho Santa Fe Inn near La Jolla became aware of the marked similarity of Pacific weather conditions during Peruvian "El Niño" years, and they became enamored with the idea that seemingly "provincial" changes involving Pacific air-sea interactions might be the key to long-range atmospheric forecasting. Namias emphasized the probable existence of atmospheric "teleconnections" that crossed the equator and linked phenomena in the Northern and Southern Hemispheres. The symposium came to a general consensus that a "unifying approach" was therefore needed to understand year-to-year climate change in the Pacific Basin. Isaacs offered up the deep-moored buoys he had been developing to monitor ocean conditions close to nuclear detonations in Micronesia as adaptable to a Pacific-wide network of ocean-atmosphere observatories. Afterward, Namias confided to Isaacs, "I have a feeling that this meeting will usher in a new era of concentrated thought and development relating to climatic anomalies in both ocean and atmosphere."[21]

For a brief moment, the Rancho Santa Fe Inn became the center of action for an interdisciplinary scientific community interested in air-sea interactions. This was not the first time this place helped shape a new form of scientific understanding.[22] In retrospect, the Rancho Santa Fe symposium changed the course of the careers of Namias and several other scientists, and it marked the clear beginning of ENSO research in the United States. The

dream of installing a vast network of unmanned buoy observatories in the Pacific also dated from this landmark meeting. This dream was premised on the need to watch for ocean-wide anomalies, particularly in the vast empty spaces along the equator. Yet the first major buoy network installed in the Pacific was only marginally related to equatorial and southern climate phenomena. This was no mere happenstance.

PACIFIC SOUTH AMERICA AS A CENTER OF ACTION

The eventual decision to limit the use of buoys to the North Pacific appears all the more remarkable when we recognize the extent of interest that developed among U.S. oceanographers and meteorologists in the waters off the Pacific coast of South America during the 1950s and 1960s. Scientists based in Southern California led the way in this regard as part of their long-standing desire to turn California into *the* center of action for Pacific science.[23] The Scripps Institution of Oceanography developed a particularly close relationship with Peruvian marine scientists starting with the Northern Holiday and Shellback expeditions (1951–1952), continuing with the IGY cruises, and culminating with STEP-I and Swansong (1960–1961), two collaborative trips focused on the equatorial and Peru current systems. This relationship focused on the reciprocal exchange of personnel such as Wooster and Peruvian naval hydrographer José Félix Barandiarán and the transfer of oceanographic instruments and techniques to Peru.[24] Significantly, Scripps encountered much less difficulty working Peruvian scientists onto its Pacific cruises than it did involving a meteorological team from UCLA during the early 1950s, when "the great current interest of meteorologists . . . regarding the role of the tropics in the general circulation of the atmosphere" had to take a backseat to the immediate forecasting demands of the Korean War on the western shore of the North Pacific.[25]

A major postwar challenge to the old European regime governing the Law of the Sea also helped stimulate scientific interest in the Pacific Ocean. In 1945, the United States unilaterally declared sovereignty over the continental shelf adjacent to its coasts at the behest of domestic oil and fishing interests. In response, Chile and Peru each claimed an Exclusive Economic Zone (EEZ) extending 200 nautical miles from its coast in 1947. Chilean and Peruvian technocrats feared the incursion of foreign fishing boats, especially California-based tuna clippers, would nip in the bud the development of their nascent fishing industries. From the beginning, these technocrats rested their claims on a scientific definition of the Peru Current ecosystem. Ecuador, Colombia, and other Latin American and Middle Eastern countries followed with similar claims. During the mid-1950s, the battle of words over this issue degenerated into a battle of blows off the Pacific coast of Latin America known as the Tuna Wars.[26]

This growing conflict had a far-reaching impact on marine science.[27] In response to requests by Mexico, Costa Rica, and U.S. tuna producers, in 1949 the United States formed the Inter-American Tropical Tuna Commission to study and suggest regulations for the exploitation of Pacific tunnids. This La Jolla-based scientific institution established a series of satellite labs in Latin America during the 1950s and served as an effective promoter of investigations in the "eastern tropical Pacific."[28] With Peru refusing to join this U.S.-dominated organization, the American Tunaboat Association entered a private licensing agreement with the Peruvian state to prevent seizure of craft operating in Peru's EEZ. This funded a marine research council in Peru and Wooster's eventual appointment as its director of investigations.[29]

No North American marine scientist showed more interest in the eastern tropical Pacific during this era than the Tuna Commission's dynamic director of investigations, Milner "Benny" Schaefer. This leading fish population biologist first became interested in the recurrence of Peru's "El Niño" in 1953 after a warming event caused a dramatic shift in tuna distribution off the South American coast. In 1954, he first became personally engaged in improving Peru's marine science capabilities when he orchestrated Peru's agreement with the American Tunaboat Association. Schaefer spent the rest of his career trying to convince his U.S. colleagues to pay more attention to the tropical Pacific and the Latin American scientists who studied it. [30]

Like his compatriot in Pacific "biopolitics," Wilbert Chapman, Schaefer viewed international scientific collaboration as the only way to establish a rational regime for the management of Pacific fishing.[31] In 1955, with these goals in mind, he began trying to hire a research meteorologist to study air-sea interactions in this region for the Tuna Commission. He found this difficult at first, but the excitement generated by the "year of change" discussed at the 1958 Rancho Santa Fe symposium (which he attended) enabled Schaefer to convince a veritable giant of the Bergen school, UCLA meteorologist Jacob Bjerknes, to investigate the relationship between Peru's El Niño and the atmospheric general circulation.[32] Schaefer also used his scientific authority over the eastern tropical Pacific to initiate a collaborative search for

a zooplankton species that indicated El Niño conditions, to place surface thermographs on dozens of tuna vessels, and to install automatic sensors at several coastal locations, including the new IGY weather station on the Galápagos.[33]

Meanwhile, the long-anticipated development of fishing industries in South America created a new vested interest in Pacific Ocean science almost overnight. From 1957 to 1962, Peru's annual catch increased from 423,894 to 6,427,244 metric tons, and Peru surpassed Japan as the number-one fish-producing country on earth. U.S. companies profited mightily from this as transporters, equipment suppliers, and outright owners of Peruvian fishing companies. Moreover, practically every fish caught off the Peruvian coast was processed into fishmeal and shipped north to be consumed by "animal factories" in the United States, Europe, and Japan. In 1959, the Peruvian state obtained assistance from the United Nations (UN) to establish a marine science research institute staffed by European and Peruvian experts. The Instituto del Mar del Perú (IMARPE)—and the export-oriented fishery to which it was tied—served as models for subsequent UN-Food and Agriculture Organization (FAO) fishery development projects, first in Ecuador and Chile (1960–1961), then several other Third World countries.[34]

These endeavors notwithstanding, East-West Cold War concerns tended to submerge Latin American issues in U.S. foreign policy during the 1950s, with the marked exception of the CIA's 1954 intervention in Guatemala.[35] Aside from "Operation Bootstrap" in colonial Puerto Rico, the United States government tended to leave projects meant to improve scientific capabilities in Latin America in the hands of U.S. universities and businesses, private philanthropists such as the Rockefeller Foundation, and international bodies such as the UN and World Meteorological Organization (WMO).[36]

Then a tectonic geopolitical shift changed the course of Cold War history in the Americas and dramatically raised the stakes involving science and North-South relations. On New Year's Day 1959, Fidel Castro and his revolutionary army made Cuba a center of world attention when they took control of one of the United States' most important informal dependencies. With rising anti-U.S. sentiment throughout Latin America, the decision by Cuba's revolutionary leadership to turn to the Soviets for help in their nationalist struggle to escape from *yanqui* tutelage virtually forced a change in U.S. policy toward development in the region. At the insistence of other Latin American leaders, the Eisenhower administration pledged support for what became the Inter-American Development Bank.[37] President John F. Kennedy promised much more. In March 1961, he inaugurated the Alliance for Progress, a decade of "maximum progress, maximum effort" toward the triumph of democracy and the defeat of mass poverty and social inequality in the Western Hemisphere. Point seven of Kennedy's original ten-point program proclaimed the need for "all people of the hemisphere . . . to share in the expanding wonders of science." The formal charter signed by Latin American leaders listed as one of its goals "strengthen[ing] the capacity for basic and applied research" in the region. More importantly, the Alliance for Progress placed experts—mainly social scientists—in positions of authority at almost every level, including "Nine Wise Men" to evaluate its progress as a whole.[38]

In Kennedy's view, the Cold War also involved "a race for mastery of the sky and the rain, the ocean and the tides, the far side of space and the inside of men's minds."[39] To make sure North-South issues were not overlooked in this struggle, Kennedy's staff quickly appointed an ad-hoc "Latin American Working Group on Earth Sciences" including Schaefer to advise the President.[40] Direct Soviet involvement in the development of industrial fisheries in Ghana, Cuba, and Chile made this all the more pressing.[41] Relatively little atmospheric or marine science were accomplished as an explicit part of the Alliance for Progress, but Kennedy's vision gave new meaning to the international projects that made Pacific South America—and tropical oceans, in general—a center of action for oceanography during the 1960s.[42]

THE EL NIÑO PROJECT

Thanks in large part to the Scripps Institution of Oceanography's postwar expeditions and the IGY, scientists understood the broad, physical contours of the Pacific Ocean, but they still understood little of the complexity of the atmosphere that overlay it, much less how these features varied over time. Since satellite and buoy observatories were still years from implementation and Schaefer's plan to use tuna clippers as scientific "ships of opportunity" had failed, U.S. scientists chose to rely increasingly on Latin American marine scientists for observations in the eastern tropical Pacific. From 1961 to 1964, the Inter-American Tropical Tuna Commission organized a collaborative oceanographic investigation of the Gulf of Guayaquil and the "frontal region" separating its warm, tropical waters from the cool Peru Current. It involved the Tuna Commission's newest member nation, Ecuador, and the Peruvian navy.[43]

Meanwhile, Jacob Bjerknes had begun to make significant progress in understanding the relationship between "El Niño" and the general circulation of the tropics.[44] From 1949 to 1957, Bjerknes headed UCLA's participation in the General Circulation Project, a large-scale international study funded by the U.S. Air Force that sought to develop a physical model of atmospheric flow over the Northern Hemisphere amenable for use in numerical forecasting. Bjerknes and his colleagues soon focused on the so-called Hadley Circulation responsible for the transfer of atmospheric energy from low to middle latitudes.[45] In 1957, Carl-Gustaf Rossby visited UCLA and tried to entice Bjerknes to return with him to Norway. Rossby wanted to reestablish Bergen as the world's center of action for geophysics. In preparation for such a move, Bjerknes diverted his attention from the Pacific to the North Atlantic.[46] But then Rossby died, the Pacific Ocean experienced its "year of change," and Schaefer convinced Bjerknes to shift his sights back toward the tropical Pacific. This conjuncture turned out to be crucial in establishing Southern California as a center for the revival of air-sea interaction science.

At this point, the new geopolitical climate influencing U.S.-Latin American relations began to affect the course of Pacific Ocean science. In November 1962, the U.S. National Academy of Sciences sponsored an Inter-American Conference on Marine Science in Miami. At this conference, a group of Pacific oceanographers drafted a plan for a series of coordinated seasonal cruises involving Latin America's new marine science organizations. They hoped to test Bjerknes's ideas connecting El Niño to changes in the Pacific's trade wind regime. Schaefer volunteered the Inter-American Tropical Tuna Commission to serve as the central coordinator for this rather modest "El Niño Project." But Office of Naval Research (ONR) and National Science Foundation (NSF) officials were not interested in funding yet another U.S.-run scientific program in the region. In the spirit of the Alliance for Progress and scientific internationalism, they wanted to use this project to establish direct liaisons with regional agencies, especially Latin American navies.[47]

This decision clearly disgruntled project planners in La Jolla. As part of their endeavor to bolster Latin America's oceanographic capabilities, these scientists had accumulated various prejudices. Some thought only the United States was capable of stimulating interest "in a group of countries . . . who do not understand the importance of the [El Niño] phenomenon to themselves, or others." Even though the data-gathering transects were simple enough for "ordinary technicians" to perform, they were loathe to allow Latin American officials to control the project's purse strings: "'something' would very likely happen to such funds before they were utilized." From long experience in the region, these scientists recognized the real difficulty of uniting traditional enemy nations under a single banner. But what they found most galling was the prospect of working with European scientists who managed Latin America's new marine science institutions. As the El Niño Project unfolded, the French director of the National Fisheries Institute of Ecuador fulfilled their worst "administrative nightmare" when he unilaterally decided to double Ecuador's funding request in order to cover "coordination costs." This almost killed the entire project. Schaefer continued to lobby for a program centrally controlled from the United States, but the ONR's top admiral decided that the ONR should deal directly with Latin American scientific organizations.[48]

Despite repeated budget shortfalls and other mishaps, the El Niño Project succeeded. Peru, Ecuador, Colombia, and Chile ran ten seasonal cruises from November 1963 to March 1966 in the eastern tropical Pacific, and they had the good fortune to observe the development of a "full-scale El Niño" in 1965. Back in La Jolla, an international team slowly compiled a groundbreaking data atlas that mapped both seasonal and yearly variation in the region. The El Niño Project turned out to be a tremendous "international triumph" for U.S.-Latin American collaboration in marine science.[49]

JOHN ISAACS'S "NORTH PACIFIC STUDY"

By 1965, oceanographers possessed a good mosaic picture of the general physical conditions of the Pacific Ocean. For some regions, this picture included seasonal changes. But except for three weather ships anchored in the northern Pacific and a scattering of island-based stations, there were few *continuous* observations suitable for following the development of an ocean-wide climate event analogous to the "extraordinary year" that brought North American scientists together at Rancho Santa Fe. The El Niño Project again demonstrated the time and effort involved in coordinating a multi-institution, multi-national scientific program—even a relatively modest one that did not cover much territory. Satellites promised to solve the problem of covering such a large region in the long term, but they were still a long way from implementation, and no one could imagine how they might peer beneath the surface of the sea.

Financial constraints were a growing concern to Pacific Ocean scientists. A crisis in yellowfin tuna production made the California tuna industry increasingly unreliable as a patron—leading Schaefer to leave the Inter-American Tropical Tuna Commission for a position next door at SIO.[50] There were clear limits to the amount of work Latin American oceanographic vessels could be expected to accomplish in the foreseeable future, and Pacific Islanders continued to be extremely dependent on their colonial rulers for financial support and technical expertise.[51] Marine scientists were not the only ones, of course, who coveted the massive support provided to the space program.[52] A network of moored instrument buoys promised a technological fix to many of these problems, especially that of attracting U.S. government patronage.

But first, someone had to develop a viable instrument buoy. Scientists and engineers at several oceanographic institutions had been working for years to develop an unmanned instrument platform capable of producing accurate data for an extended period of time. The extreme environmental conditions of the open ocean posed several technological challenges. These included buoy stability, instrument reliability, communicating with the buoy, and the difficult task of recovering an expensive instrument platform when a problem surfaced. Even in favorable conditions, waves and currents converted a buoy and its mooring line into an oscillating system that subtly altered the local environmental conditions its instruments were designed to measure. Buoy designers had to learn to correct for this. To these ends, designers considered a wide range of geometric forms.[53]

Scripps scientists first tested deep-moored buoys at the Pacific Proving Ground to observe the effects of nuclear tests at various ocean depths.[54] John Isaacs started working in earnest on deep-moored buoys at SIO after the 1958 Rancho Santa Fe Symposium. He was almost uniquely suited to the task at hand: he was one of only a handful of oceanographers who combined an extensive background in engineering and honed technical skills with prestige and authority as a scientist—practically all of which he had acquired "on the job."[55] Isaacs explicitly strove toward installing a "relatively simple" buoy monitoring network that covered the entire Pacific Ocean. To this end, he worked on a small "bumblebee" buoy suitable for installation in "swarms" around large "monster" buoys equipped with long-range radio equipment then under development by the San Diego-based Convair corporation. At first, Isaacs worked on a cheap "catamaran type instrument float"; he eventually settled on a more expensive, more seaworthy metal disc design (Figure 3). By 1965, he felt confident enough in

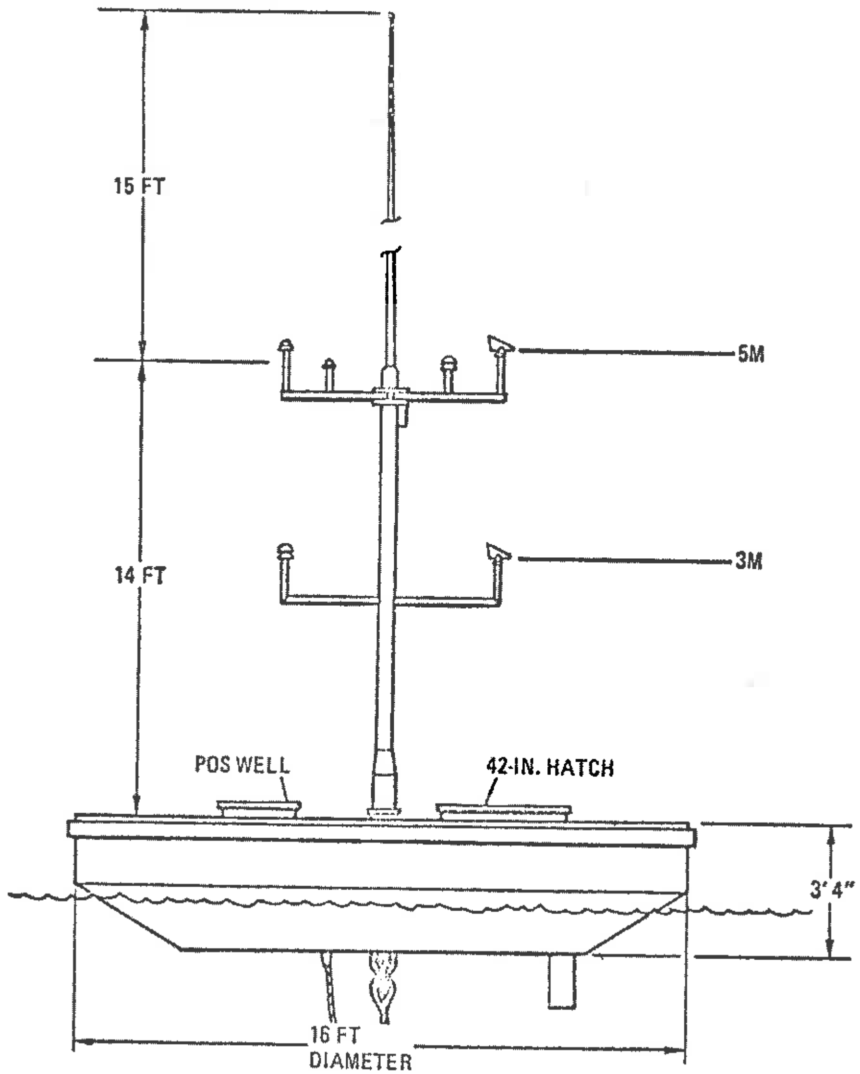


FIGURE 3. Modified version of John Isaacs's "bumblebee" buoy design, 1972.

these instruments to begin handing around a draft project proposal to investigate the "boundary currents of the Eastern Pacific" using an array of 70 to 100 stations stretching from Alaska to Peru (Figure 4). This array would be centrally operated from La Jolla, Isaacs's home and the reigning metropolis of Pacific oceanography.[56]

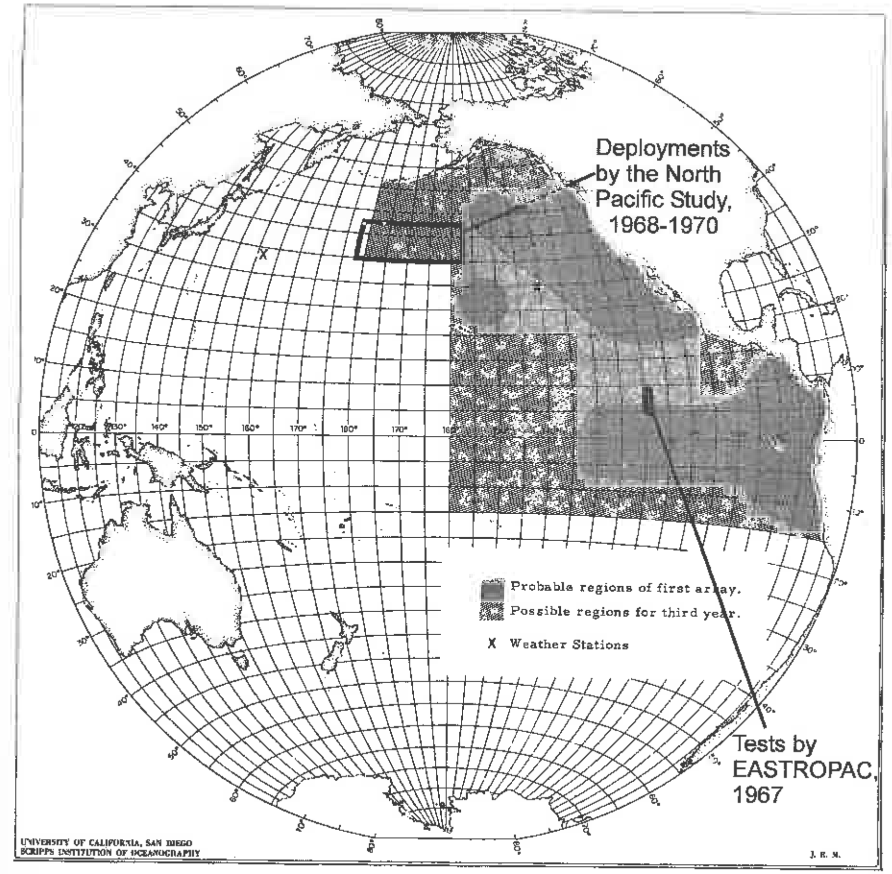


FIGURE 4. Map of prospective buoy placements, 1965, and actual deployments, 1967–1970.

This proposal was a direct offspring of the 1958 Rancho Santa Fe symposium. Isaacs clearly wanted to put his buoys in position to observe a similar ocean-wide anomaly. Now he had to create a constituency of interested scientists and locate a patron for this grandiose plan. Jerome Namias showed the most interest in Isaacs's plan; he advised Isaacs to play up the importance of his project for the emerging field of air-sea interaction studies. Isaacs responded by inviting Namias to Scripps for several days to discuss "Long-Range Forecasting of the Atmosphere and its Oceanic Boundary." Many readers of Isaacs's first draft advised him to scale down the overall size of the buoy network in order to attract funding. One reader recommended a small, two-year study that would test the reliability of this still unproven technology in the California Current close to home. Nevertheless, Isaacs retained the large network and placed great emphasis on large-scale "teleconnections" and the "celebrated . . . El Niño of the Peruvian Coast" in his first formal proposal.[57]

The Office of Naval Research pushed Isaacs in a different direction. He got a clear message from ONR officials that his buoy project should be "nationalistic in bent" and "based on well understood areas," instead of regions far afield such as Peru. It should also serve a host of scientific fields, "possibly even oceanographers," Isaacs noted privately.[58]

One big selling point for buoys emerged at this time: their practical relevance to "military scientists." The advent of Soviet long-distance, deep-diving nuclear submarines and land-based ICBMs in 1957–1958, the "year of change," fundamentally changed the way both sides of the Cold War conflict conceived naval warfare. Under nuclear power, Soviet subs could maneuver close to U.S. targets and linger for weeks. Meanwhile, the Soviet navy began targeting its missile-toting subs against Western naval attack. This made acoustic submarine detection all the more important to U.S. naval strategists. The Navy needed detailed knowledge of the vertical temperature structure of the Pacific to interpret acoustic data properly. Instrument buoys promised to increase the United States' anti-submarine capabilities by locating anomalies in thermocline depth where Soviet subs could escape detection. This had obvious implications for locating Isaacs's buoys: they would only serve military interests if they were placed in regions with significant submarine activity, i.e., the North Pacific.[59]

Not everyone from the ONR on these "high-powered committees" was obsessed with "nuts and bolts" or the national interest. At least one official embraced Isaacs's vision of the role buoys might play in "a rational plan" to study "a whole ocean."[60] But practicality pushed these concerns into the background, at least for the moment. Buoy tests near Midway Island in 1966 encountered unforeseen difficulties, most related to human use of the sea: fish bite damage, ship collisions, entanglement with long-line fishing gear—perhaps even vandalism by other ocean scientists. In his revised budget, Isaacs felt it necessary to allocate the same amount to mooring tests, service, and buoy replacement as to basic construction, installation, and data analysis. This dramatically increased the logistical requirements of the project and eventually forced him to scale it down to one-fifth of its initial size.[61]

In close consultation with Namias, Isaacs adjusted his theoretical justifications to reflect this new calculus. Isaacs now pretended that the project had developed directly out of a desire to "understand the nature of . . . large scale variations in oceanographic conditions in the *North* Pacific."[62] Namias was excited by the possibilities for long-range forecasting offered by a "spare grid" of stations placed near the "center of action" of cyclone formation in the Gulf of Alaska. In 1965, he had successfully tracked the propagation of persistent anomalies in this region using hemispheric maps centered on the North Pole. He believed these large anomalies had developed *in situ* from smaller anomalies in the region. Enthusiasm among meteorologists for long-range forecasting and Namias's work as chief of the Extended Forecast Division at the U.S. Weather Bureau was approaching an all-time high, so his arguments carried special weight.[63]

In retrospect, it is easy to see how Namias's preferred analytical tool and his ties to the old Bergen school shaped his geographical bias toward the far North Pacific. Carl-Gustaf Rossby originally taught Namias how to use polar projections as part of the Bergen school's old emphasis on "the polar front theory of atmospheric circulation" and "semi-permanent centers of action." In fact, Rossby used a polar projection of middle-atmospheric pressure on Christmas Day, 1940, prepared by Namias to calculate the propagation speed of atmospheric long waves for a real case for the first time. Rossby was able to accomplish this because Namias had access to data stretching from the northwestern Pacific to the North Atlantic.[64] Their lasting importance to Namias is clear in the published version of his 1965 lecture at SIO.[65] The many uses of polar projections notwithstanding, they literally pushed the tropics to the margins.

Ironically, one of the original architects of the polar front theory turned out to be the biggest critic of Isaacs's shift in focus. At an August 1966 meeting to discuss Isaacs's new proposal, Jacob Bjerknes objected to Namias's understanding of the "source area of anomalies." Both Namias and Bjerknes looked to the old Bergen school for inspiration in their search for "the causes of climatological variations." But based on his work for the Inter-American Tropical Tuna Commission and an intense study of the reports generated by the 1958 Santa Fe Symposium (especially Namias's contribution), Jacob Bjerknes argued forcefully for a focus on tropical "energy interchanges." Nevertheless, he eventually joined the consensus that Isaacs's buoys should first be used to study higher latitudes.[66] At this meeting, Namias and Bjerknes publicly initiated a collegial debate regarding the cause of large-scale anomalies in the Pacific Ocean, while Isaacs's proposal came of age as the *North* Pacific Study.

Over the next four years, the North Pacific Study installed two Convair "monster" buoys built for long-range radio communication and an eventual total of sixteen bumblebee buoys, all equipped to measure conditions down to 300 meters. This was the first large-scale installation of instrument buoys in the Pacific. Following Namias's plan, these buoys were deployed in a broad band south of the Aleutian Islands to watch for "centers of abnormality" in this supposed "birthplace of American weather" (Figure 4). As feared, nearly half of their sensors failed (especially the anemometers and all important bathythermographs). Only ten moorings provided data for a long period after deployment. But some worked as long as twelve to eighteen months, much better than the expected failure rate.[67]

The North Pacific Study further cemented La Jolla's place as a "center of action" for the emerging field of air-sea interaction studies. Everyone knew that the politics of institution building were intimately involved in such projects. If there was a "race" in buoy development, then the SIO was clearly winning, with its first group of ten buoys in the water by August 1968. On the Atlantic Coast, the ONR-funded National Data Buoy Center (NDBC) installed its first "monster" buoy in the Gulf Stream off Norfolk, Virginia, in February 1970. By 1976, the NDBC still only operated four such disc buoys, including one in the Gulf of Alaska.[68] More importantly, the North Pacific Study (and a furnished house) enticed Jerome Namias to leave the U.S. Weather Bureau in Washington, DC, and join the Scripps Institution of Oceanography. Namias's presence, in turn, convinced his long-time friend Bjerknes to spend more of his time in La Jolla. Namias and Bjerknes responded to the stimulus of each other's presence by publishing a flurry of papers on air-sea interactions, including Bjerknes's classic article that first recognized the "Walker Circulation" over the equatorial Pacific (a key atmospheric feature of ENSO), and a paper by Namias that identified a marked shift in the overall climatic regime of the northern Pacific during the sixties.[69] Thus, Isaacs's long-standing effort to bring meteorologists into Scripps's community of oceanographers immediately bore a rich harvest.

FROM EASTROPAC TO IPASS

The existence of a competing program provided Washington-based bureaucrats with another good reason to limit the geographical focus of the North

Pacific Study. Since 1960, Pacific scientists had been planning a "Cooperative Effort towards Understanding the Oceanography of the Eastern Tropical Pacific Ocean." This project was explicitly designed to test Bjerknes's hypotheses regarding El Niño and to provide California fishermen with a better understanding of tuna distribution as they switched from the overexploited yellowfin to the unpredictable skipjack.[70] Late in 1966, after years of tortuous planning, EASTROPAC finally got underway. This was truly a vast undertaking. It involved ten U.S. institutions and thirteen oceanographic vessels operating around the equator from February 1967 to March 1968. As a direct extension of the El Niño Project, scientists from Peru, Ecuador, Chile, and now Mexico, were intimately involved in the planning and implementation of EASTROPAC and influenced some of its goals. Their inclusion again helped sell the project to Washington during this decade of scientific internationalism.[71] With a view toward extending systematic coverage of the tropical Pacific "through several annual cycles," SIO tested three of Isaacs's data buoys at the so-called meteorological equator as part of EASTROPAC (Figure 4).[72]

In 1970, the United Nations inaugurated the International Decade of Ocean Exploration (IDOE). Scientific internationalists behind this multilateral program hoped a sustained, cooperative effort in the spirit of the IGY and the on-going Global Atmospheric Research Program (GARP) would lead to the rapid "conquest" of the oceans and atmosphere by science.

Under the auspices of the National Science Foundation, in April 1970, approximately 30 scientists interested in Pacific ocean–atmosphere interactions met at Oregon State University to draft a program to replace EASTROPAC and the North Pacific Study. They hoped to take advantage of a big chunk of the US$5 million specifically slated by the NSF each year for environmental forecasting projects under the IDOE. Even though many bugs still had to be worked out of moored buoys as instrument platforms, Pacific scientists thought they were in a good position to begin planning for a larger sensor network. In fact, NSF-IDOE guidelines may have been written partly with this group in mind: they explicitly favored "broad and interdisciplinary" studies of oceanic variability, upwelling, energy flow, and air-sea interactions "with emphasis on directly applicable results beneficial to mankind." Three marine scientists from British Columbia and one from Tokyo attended this initial planning session. Unlike many Pacific oceanography conferences during the 1960s, no Latin American scientists were invited, though proposals for future participation by Ecuador, Peru, and Chile were included among the discussion papers. The NSF-IDOE's primary stated goal, after all, was to provide "increased opportunities for international cooperation and cost-sharing" and results "applicable to regions of interest to other nations"—though with an important caveat: "*geographical location to be determined by U.S. national interest.*"[73]

But first this group had to decide which regions of the Pacific interested them. Namias and those in favor of an expanded North Pacific Study dominated the first day. Then Wayne Burt, the organizer of the meeting, pointed out the glaring lack of observations from the equatorial and southern Pacific. Since stepping down as chair of Oregon State's flourishing oceanography program in 1967, he had become extremely interested in tropical air-sea interactions and begun working closely with William Quinn, a long-time Air Force forecaster who had just completed a Ph.D. in physical oceanography at Oregon State. In preparation for this meeting, Burt had gone on an exploratory trip to South America and returned with detailed plans for Latin American participation.[74] His comment reopened the Namias-Bjerknes debate. "We must include the eastern tropical Pacific in our study," Bjerknes pleaded. In a pre-session memorandum, he had already lamented the closure of the Canton Island meteorological observatory late in 1967 after seventeen years of operation. Radiosonde data from this desert island in the central Pacific had been critical to his discovery of the Walker Circulation, a quasi-annual variation in atmospheric convection above the equator. Behind the scenes, he and Namias were engaged in an intense mini-debate over his public declaration that the anomalous 1969 rainfall in Southern California might have been predicted if the Canton facility had remained open. Namias responded to Bjerknes's challenge by reiterating the importance of Arctic and temperate zone phenomena.[75] Others chimed in with their own pet interests. John Isaacs, for example, suggested paleoclimatic studies "to determine what part man is to blame for and what part nature is to blame for" in recent climate change. But inter-annual oceanic anomalies—especially those known to be related to the El Niño phenomenon—remained at the top of everyone's list of favorite "centers of action."[76]

The conversation soon turned to technology. Could this group design a project that would produce continuous observations of the quality of Bjerknes's beloved Canton Island data from a network of locations over several years? Isaacs, as always, made a plug for his moored buoys. In this vein, Burt and Quinn had already been working on a proposal to install a line of equatorial buoys to test Bjerknes's Walker Circulation theory.[77] Bjerknes, meanwhile, cautioned that observations from the new generation of infra-red detecting satellites still could not come close in detail or accuracy to surface-

based observations. Others suggested much simpler technological approaches. Ted Saur, a Bureau of Commercial Fisheries oceanographer, advocated the massive use of expendable bathythermographs (XBT), small drifting buoys released by ships of opportunity. These would only cost US$20 per observation, although frequent observations could only be made in major shipping lanes. Quinn, expanding on Bjerknes's suggestion to reopen the Canton Island facility, called for a series of land-based meteorological stations in the southeastern Pacific to watch over the anticyclonic "center of action" associated with the Southern Oscillation. Klaus Wyrtki, a physical oceanographer based at the University of Hawaii who had worked closely with Peruvian scientists and published several articles on the Indian Ocean and eastern equatorial Pacific, suggested a large network of Pacific island tide gauges. Combined with synoptic data from Quinn's grid of stations, he thought he could devise a method to deduce general atmospheric and oceanic conditions over vast regions of the Pacific from this sea-surface topography.[78] After "squabbling like children," this group finally drew up a map for an observation network that made use of all of these techniques. Namias's interest in the North Pacific only figured as a small part of an observation network that covered much of the Pacific Ocean.[79]

Now this emerging air-sea interaction group had to put together an "integrated proposal" to justify this grandiose network to the NSF. It had taken years to obtain the go-ahead for EASTROPAC. At the next planning meeting, their first integrating act was to restrict participation to U.S. Pacific Coast scientific institutions. They chose Bjerknes and Namias to convince NSF representatives that "Integrated Pacific Air-Sea Studies" (IPASS) were a "good investment" toward the improvement of long-range forecasting.[80] The NSF-IDOE's deputy chief initially criticized their lack of a central problematic, realistic budget, and firm plans for international participation. He was not overly pessimistic, however, and recommended a simple solution: if those interested in Pacific air-sea studies really wanted to integrate their program, they needed to establish an organizational structure with a single decision maker at its center. To this end, project planners immediately drew a rough map dividing the Pacific Ocean into territories, each under the control of one or two senior scientists. Wayne Burt turned over management of the project to John Isaacs in view of his buoy program's achievements and SIO's recent success organizing JOIDES, a multi-institution oceanographic program to drill a deep hole into the earth's crust. (JOIDES represented a reaction to the unwieldy apparatus that sank the MOHOLE program.) Isaacs turned over active program management to Richard A. Schwartzlose, an oceanographer who had been intimately involved in his projects since the Rancho Santa Fe conference. They were left to bring the program "down to a manageable size, scope and budget," hopefully for implementation in 1972.[81]

During the next round of planning, Isaacs and Schwartzlose explicitly framed IPASS as an exercise in scientific internationalism. They portrayed it as an extension of the North Pacific Study to the equatorial and southern Pacific in order to produce quantitative data clarifying the existence of "teleconnections" linking El Niño and the Southern Oscillation to North America.[82] They made room for immediate participation by Chile, Peru, Ecuador, Canada, and Mexico (in order of importance), and left open the option of including New Zealand, Great Britain, France, and Japan. (Significantly, they left out Australia, home of a resurgence of interest in the Southern Osciallation.)[83] At the suggestion of NSF referees, they brought Warren Wooster and the Inter-American Tropical Tuna Commission on board to orchestrate South American relations. In their sub-proposal, Burt and Quinn highlighted their plans for participation by David Enfield, an oceanography graduate student fluent in Spanish with four years of experience teaching physics in Chile.[84] Even Namias gave in to his colleague's emphasis on the tropics at this point, though he still preferred to attribute tropical sea-surface temperature variability "to meteorological-oceanic events in temperate latitudes."[85] In what turned out to be a wise move, Namias continued to emphasize the immediate significance of his recent work for long-term forecasting over North America.[86]

Deep-moored buoys were to be the workhorses of this project. IPASS administrators developed four alternative plans. The most ambitious would have installed 69 instrument buoys of various classes, required 27,000 miles of ship travel per year, and cost US$20.2 million over five years—the lion's share of the NSF-IDOE's budget for environmental sensing projects. Project organizers tended to assume buoys' long-term reliability, at least in their written proposals. In effect, this turned them into "black boxes" sold as part of a technological system.[87]

FROM IPASS TO NORPAX

Meanwhile, the tide seemed to be turning in favor of Integrated Pacific Air-Sea Studies. In October 1970, a physical oceanographer with deep ties to SIO, Feenan Jennings, left his position as deputy director at ONR and took

over as director of the entire NSF-IDOE program, a position he held for the next eight years. This bode well for IPASS, as Jennings had been present at all of the major planning sessions for Isaacs's North Pacific Study and was a well-known advocate of buoy-based observatories.[88] Project participants underscored the importance of tropical and southern Pacific observations in private correspondence with Jennings and tried to reassure him that their program was under firm guidance.[89] But Jennings was not convinced. He dismissed South American ship operations as irrelevant "side programs." He also thought, based on others' experience with tide gauges in the Atlantic, that Wyrtki's study was doomed to failure. Both features confused IPASS's "core program," as he saw it, to make "a significant contribution" in the near term to meteorological and oceanic forecasting. Jennings also questioned the willingness of West Coast universities to dedicate "necessary research talent" and ship time to the program.[90]

About this time, Isaacs and Schwartzlose approached the Office of Naval Research for help.[91] The Navy had much deeper pockets than the NSF-IDOE. Together, the NSF and ONR tentatively offered to fund IPASS at the highest level requested. As we have already seen, ONR officers had a much more rigid view than the NSF regarding which centers of action in the Pacific deserved their attention. Following the lead of their recently departed colleague, Jennings, they embraced Namias's opinion that mid-latitude dynamics were much more important to weather prediction in the United States. They directed the IPASS team to "concentrate on the North Pacific Ocean in order to adequately perform the research within the level of funding and competent scientific manpower available and in order to maximize the potential practical benefit." Only in strictly limited and "thoroughly justified" instances would they allow an extension of the project to the equator.[92] The ONR also had a narrower concept of which oceanographic centers deserved their support. The ONR wanted the entire program to be centered at SIO, with the private defense contractor General Dynamics taking full control of hardware manufacture, installation, and maintenance. The NSF-IDOE, however, continued to insist on a multi-university project.[93]

The available evidence only allows me to speculate as to why Washington bureaucrats turned their backs on the idea of an "International Decade of Oceanic Exploration" and a sensory network that spanned a whole ocean at this juncture.[94]

NSF and ONR referees had reasons to question the scientific merits of the proposal besides those already mentioned. For decades, meteorologists had been trying to make use of "teleconnection" phenomena such as the Southern Oscillation to predict the weather, with little success.[95] These referees wanted to fund a program likely to produce tangible results, not a "general study of teleconnection phenomena."[96] From this point of view, Namias and his interests clearly represented the safer investment. He was a senior scientist at the peak of his career with a long record of practical accomplishments. Bjerknes, his proven "research talent" notwithstanding, was over 70 and had become interested in risky, speculative ventures. Quinn, on the other hand, was new to oceanographic research and an unproven commodity.

Isaacs's instrument buoys still retained their cachet as a new, high-tech weapon for fighting the Cold War. In 1968, the Soviet navy began deploying *Yankee*-class ballistic missile submarines off the U.S. coast on a large scale, thus raising the stakes of submarine detection yet again. This was but one feature of a massive military build-up that converted Leonid Brezhnev's Soviet Union into a genuine, global superpower and pushed the Nixon administration toward a policy of détente.[97] Feenan Jennings made it abundantly clear to IPASS planners that the prospect of a large buoy network in the North Pacific was the most attractive component of their program. As the planning for IPASS dragged out, Washington officials even considered deploying a network separate from any research program with the hope that scientists would eventually derive some "valid, usable scientific data."[98] At least from Jennings' point of view, this was a technology-driven project.

Such comments indicate why he was uninterested in tide gauges and island observatories, but they do not fully explain why Washington officials considered Latin American participation unimportant. This non sequitur is especially glaring considering the amount of effort they spent cultivating relationships with South American marine scientists during the mid-1960s. Changes in the North-South dynamics of the Cold War may have influenced their thinking on this point. "Vietnamization" was the buzzword of the day. This meant slowly turning over the burden of containing the communist threat to friendly authoritarian regimes (no matter how brutal) in South Vietnam, Iran, Zaire, and other Third World countries. In Latin America, this marked a repudiation of the Alliance for Progress, which was allowed to expire in 1970 after accomplishing few of its goals.[99]

This policy did not necessarily entail scientific disengagement from Latin America. From 1968 to 1971, the United States contributed US$13.8 million worth of matching funds explicitly intended to give an "unprecedented impetus" to science and technology in the region, including marine science projects in Argentina, Mexico, Peru, and Venezuela.[100] By providing support to "national" organizations for the promotion of science, such as Peru's National Council on Science and Technology (CONCYTEC, est. 1968), however, these programs encouraged the growing perception that Latin Americans were ready to support "independent scientific traditions." This was, after all, the heyday of national liberation movements and dependency theory in the Third World.[101]

Such nationalist attitudes had direct repercussions for marine science in the Pacific. At a quadripartite scientific conference in April 1968, U.S. representatives offered to fund a supra-national organization to coordinate and centralize fishery science investigations for the entire southeastern Pacific. This would have given a big financial boost to marine science in Peru, Ecuador, and Chile. But it came with a condition: U.S. vessels would be allowed to operate within the 200-mile territorial seas claimed by these states without paying license fees or fear of capture. They unanimously rejected this proposal and stated their intent to rely on their own scientific and economic resources. The achievements of scientific internationalism in this region during the previous decade made this a realistic possibility. In the years that followed, rabid nationalists at the head of Peru's Revolutionary Government of the Armed Forces (1968–1975) and Chile's Popular Unity government (1970–1973) converted such anti-U.S. sentiment into broad public policy. Many U.S. marine scientists, including several involved in the events described here, viewed the 200-mile territorial sea as a direct threat to their interests.[102] The fact that fishery studies were explicitly excluded from the NSF-IDOE charter (and Latin American institutions were mainly—but not exclusively—oriented toward fisheries) made it that much easier to leave South American marine scientists to their own devices.[103]

Whatever its motivations, this abrupt turn of events at the "center of action" for funding U.S. marine science led to the immediate reorganization of IPASS and came close to eliminating El Niño and the equatorial Pacific from its purview. SIO's director William Nierenberg, a man with long experience saving troubled oceanographic projects from doom, agreed to take responsibility for seeing that this project was reorganized under a rigid administrative hierarchy at Scripps.[104] Nierenberg's support for this project pushed SIO much further toward becoming a major center for climate change research.[105]

A progeny of the age of Big Science, the professional project administrator, took on a crucial role in this context. Tim P. Barnett, a home-grown physical oceanographer from SIO and long-time coordinator of the North Pacific Study, deserves much of the credit for saving this foundering program and turning it into a reality.[106] During the summer of 1971, Barnett traveled to Washington to meet with NSF and ONR officials. He returned to La Jolla with the explicit mandate to bridge the "large communication gap" separating air-sea interaction scientists and their patrons and to "take a strong role" in guiding an "expanded North Pacific Study" through its remaining bureaucratic hoops.[107] Except for John Isaacs, who remained senior project director, the other IPASS scientists were relegated to an advisory role.[108]

Under Barnett's command, the central purpose of this program became "*to investigate and describe the mechanisms responsible for the large scale oceanic and atmospheric fluctuations that occur in the mid-latitudes of the North Pacific Ocean and thus gain a better understanding of North American weather and climate.*" Nevertheless, he used his power to make sure tropical processes remained a part of the project. He defined the "equatorial current system" and "equatorial atmospheric circulation" as the southern boundary under the program's purview, and he identified Bjerknes's "Walker circulation" theory as the first hypothesis to be tested by this "experiment." By excluding the Southern Hemisphere, Barnett consciously left out an important part of the physical mechanism most of his scientific team thought controlled the Walker Circulation. Thus, Barnett was fudging a bit when he claimed to examine the workings of "the *total* system" of large-scale, air-sea interactions affecting the northern half of the Pacific basin.[109]

Barnett's initial description of a second hypothesis to be tested by this "experiment" focused on changes in the North Pacific trade winds—an important focus of the 1958 Rancho Santa Fe Symposium.[110] Under pressure from Namias, he completely changed this section to propose a test for Namias's contention that *in situ* air-sea feedback in the "Subarctic Frontal Zone" was primarily responsible for "anomalous weather regimes" over the North Pacific and western United States. Barnett also added Namias's pet phrases to the project's main statement of purpose defining "the mid-latitudes of the North Pacific" as "the breeding place of North American weather" and the key to "long-range prediction." As a nod to his other colleagues, he also added references to "interhemispheric connections" that emphasized the importance of the Southern Oscillation. Even though "order," "cohesion," and "organized attack" were keywords in Barnett's proposal, he was no autocrat.[111]

He also shared his colleagues' vision of a hemispheric system of data buoys that far exceeded the geographical limitations set by Washington officials (Figure 5). He provisionally proposed a *nine*-year program that would have deployed its first group of buoys in the north-central Pacfic, but soon would have given extensive attention to the eastern tropical Pacific. In sub-

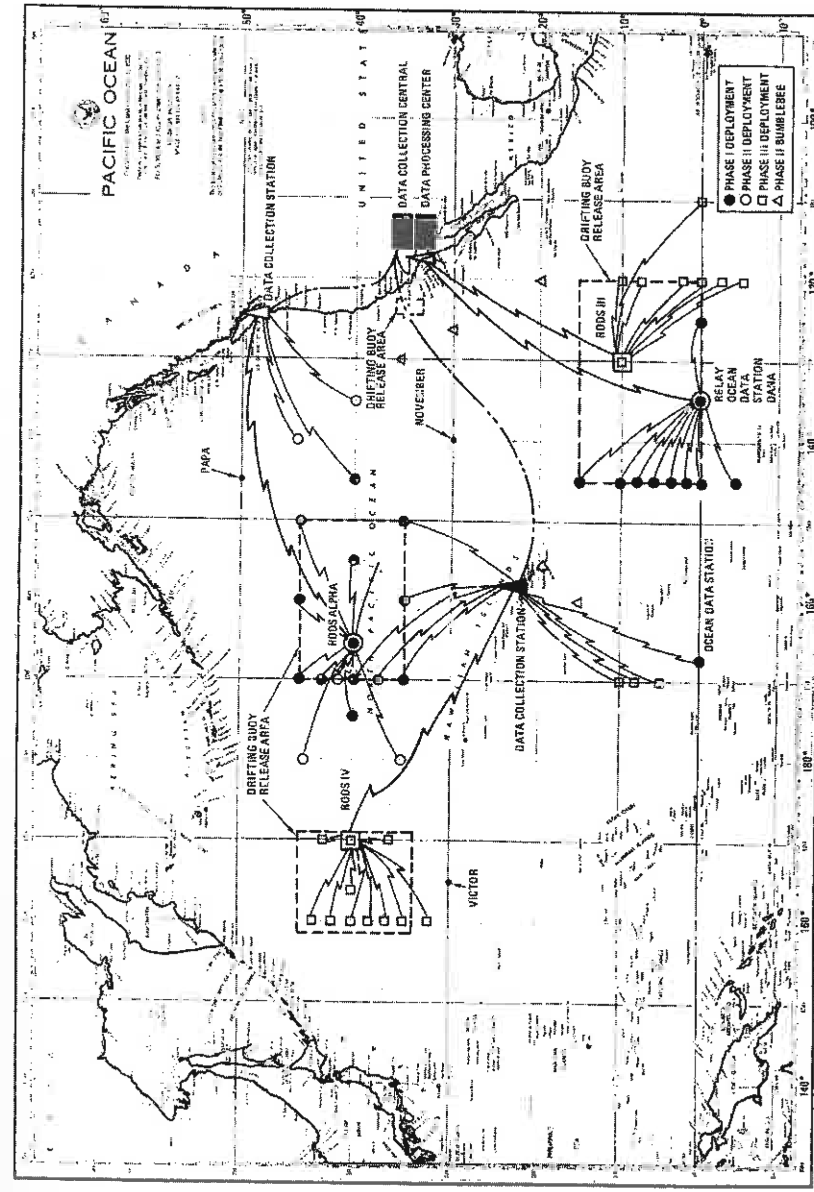


FIGURE 5. Tim Barnett's initial plan for phased buoy deployment by NORPAX, 1971.

sequent revisions, Barnett shifted the studies' focus toward the northern Pacific, but always retained a line of equatorial buoys north of the Marquesas.[112] Barnett also gave a nod to international participation in his initial proposal. He expected Canada's Ocean Station Papa to take an active role, and planned to request historical data from Japan, the USSR, Great Britain, New Zealand, and "investigate the possibilities" for exchange with "Latin American countries."[113] But he virtually deleted international participation from his second proposal. He only retained one vague reference to possible contributions by Japanese, Soviet, and Latin American scientists. La Jolla was to be the real center of this network.[114]

Some of Barnett's changes were hard for others to swallow. Warren Wooster abruptly dropped out of the program when he sensed it drifting northward. Bill Quinn and Wayne Burt, the initial organizers of the IPASS group, had to change their plans the most. Barnett irrevocably axed their proposal to obtain new meteorological data on "the little-known core of the Southern Oscillation" in the southeastern Pacific. Quinn reluctantly agreed to join Bjerknes's study of the equatorial Hadley cell, while Burt faded out of the program.[115] But Klaus Wyrtki refused to give in. He and Bjerknes provided justification after justification for equatorial tide stations, "the most closely scrutinized and discussed subprogram" of the entire proposal. Finally, in the summer of 1972, Washington officials relented and gave Wyrtki permission to install four stations (of an original 50). This forced Barnett to scramble to write tide stations back into his proposal.[116] Wyrtki narrowly prevented the elimination of the central equatorial Pacific from this buoy-centered study.

By this time, NSF and ONR officials had given their seal of approval to most of Barnett's changes and directed SIO to gear up for what was then conceived as a three-year, $16 million program. Barnett's skill at formulating an "experiment" to decide the Namias-Bjerknes debate saved the project. In view of its narrowed focus and prevailing scientific fashion, IPASS was re-christened the North Pacific Experiment (NORPAX).[117]

THE RETURN OF EL NIÑO

It took another year of organizing before NORPAX took physical shape. In January 1974, NORPAX deployed its first buoy at 35°N 155°W as part of its "POLE" mini-experiment. During this opening phase, NORPAX administrators elected to slow buoy deployment to a snail's pace and focus on several short-term, "obtainable goals" that would have an immediate payoff

and attract further funding.[118] Such small-scale "experiments" using a variety of sensing techniques, rather than a large-scale buoy network, emerged as NORPAX's primary focus.

In the meantime, NORPAX scientists were totally out of position when their main quarry—a major El Niño event—made an abrupt appearance. In 1972–1973, a climate anomaly much stronger than the 1957–1958 event caused global havoc: El Niño applied the coup de grace to the overdeveloped Peruvian fishing industry. The West African monsoon failed, causing severe drought and famine in the Sahel, while the Soviet Union experienced a heat wave so severe it was forced to buy wheat from the United States.[119] Latin American scientific institutions luckily had ships in position to observe the development of this phenomenon in the eastern tropical Pacific.[120]

NORPAX scientists recognized what they had missed. Even Namias was becoming interested in tropical meteorology by this time.[121] At the 1974 Eastern Pacific Oceanic Conference, based on Southern Oscillation data, Quinn predicted the resurgence of El Niño in 1975. Chastened by the lost opportunity of 1972–1973, Wyrtki submitted a proposal to the NSF-IDOE through NORPAX to organize an oceanographic cruise in early 1975 "to explore the birth and life history" of an El Niño as it unfolded. Such plans usually took months to implement. By lucky coincidence, there were two ships in the area close enough to survey a region near the Galapagos in February and March 1975. This El Niño failed to materialize. Quinn reported to NSF officials that they had witnessed a "mini-El Niño"—a classic case of post-hoc rationalization for a failed prediction. He proposed the organization of an El Niño Watch that would keep oceanographic ships on alert for future events.[122] Quinn never really found a home at NORPAX, however, and he drifted toward historical studies of El Niño and the Southern Oscillation. Based on this archival work, he developed a series of extremely influential (albeit flawed) chronologies of these events.[123]

The 1972–1973 El Niño did not lead NORPAX administrators to accelerate their buoy deployment. Befitting its name, NORPAX never implemented a moored buoy network in the equatorial Pacific. Instead, it directed its efforts toward expendable bathythermographs (XBTs): small, spar-type drift buoys that could be deployed by either ship or aircraft. XBTs took advantage of cutting-edge global positioning technology and were becoming an instrument of choice for large collaborative programs such as the World Meteorological Organization's Global Weather Experiment.[124] In November 1977, EPOCS, an entirely separate program funded by NOAA, deployed the first research-grade moored buoy network in the equatorial Pacific.[125]

As it turned out, of all the instruments at NORPAX's disposal, Wyrtki's sea-level gauges produced the most valuable data. The 1972–1973 El Niño helped him to garner funding for a much larger network. NORPAX also elected to install meteorological sensors on three of the "Line Islands" crossing the equator far west of the Galápagos.[126] These tide gauges provided continuous data from fixed locations and soon enabled Wyrtki to chart the development of ocean-scale events. He used this relatively simple instrument network to produce a series of fundamental articles in the *Journal of Physical Oceanography* that directly related changes in equatorial sea level to the physical development of El Niño events.[127] Tim Barnett, in the meantime, left his administrative position to pursue climate research under NORPAX. Despite Namias's caution regarding "the long and dismal history of such attempts," Barnett developed significant "skill" using advanced statistical techniques to predict long-range changes in North Pacific trade winds and North American air temperatures from changes in tropical sea-surface temperatures. By 1981, Namias was ready to admit that Barnett had produced evidence that "tropical Pacific SST predictors of U.S. temperatures are more skillful than mid-latitudinal Pacific SSTs."[128] These men did not need high-tech instrument platforms to confirm Bjerknes's hypothesis that changes in the equatorial Pacific had a significant, predictable impact on North American weather. Unfortunately, Bjerknes passed away in 1975 before he could contribute much to NORPAX.[129]

All this happened *before* the onset of a "super-ENSO" in May–June 1982. As we saw at the beginning of this chapter, there was no fixed buoy system in place to observe the development of this extremely powerful event. The initial failure of Pacific scientists to detect these changes has led many to forget NORPAX's accomplishments.[130] In fact, NORPAX and EPOCS scientists foresaw that a satellite-based system would have difficulty detecting an unexpected oceanic anomaly.[131] But even they were surprised by the speed and strength of this event. Latin American oceanographers came to the rescue, as they had in 1972. EPOCS and a consortium of Latin American scientific organizations quickly set up an ad hoc observation network, the Estudio Regional del Fenómeno El Niño (ERFEN). Under the circumstances, this group did an excellent job monitoring this major climate event, most importantly, by releasing a host of satellite-linked drifting buoys near the South American coast. This was yet another positive legacy of 1960s scientific internationalism in Latin America.[132]

It was impossible, of course, to make up for the lack of oceanographic observations during the early stages of this ENSO event. Thus, the geopolitics of instrument buoys during the long "twilight struggle" of the 1960s and 1970s determined what it was possible to know about the geophysics of the earth. Individual ocean scientists nevertheless demonstrated their tenacity to choose which "centers of action" in the Pacific Ocean interested them—as long as they were not too far removed from the power centers of Cold War science.

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NOTES

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CHAPTER 6

Breaking New Ground

The Origins of Scientific Ocean Drilling

DAVID K. VAN KEUREN

INTRODUCTION

The 1960s' revolution in the earth sciences dramatically reshaped the way in which scientists and public alike viewed the history of the planet.[1] The work of Harry Hess, Robert Dietz, D.H. Matthews, F.J. Vine, and J. TuzoWilson, among others, was of critical importance in providing a new theoretical and interpretive framework for explaining the geological history of the continents and sea floor. But other advances in understanding the history of the planet quickly followed. In particular, the results of a concerted and ongoing effort in scientific deep sea drilling (which commenced in 1968) eventually provided marine geologists with a detailed look at many geological features never seen before. Almost the entirety of the sea floor—hitherto only known through limited sampling work—became available for observation and laboratory analysis by marine scientists.[2] The results were truly remarkable and greatly enhanced understanding of many of the finer details of historical marine geology.

The *Glomar Challenger*, drill ship for what became the Deep Sea Drilling Project (DSDP), came on line in 1968. Arthur Maxwell, who was co-chief scientist for the third leg or cruise of the *Challenger* in 1971, later remarked that the ship produced scientific results that were "nothing short of revolutionary."[3] Indeed, his cruise helped provide yet further observational evidence of the accuracy of sea floor spreading and continental drift.[4]

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